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THE EFFECT OF EXTENDED DAY LENGTH ON EARLY SEXUAL MATURATION AND GROWTH IN ATLANTIC SALMON (SALMO SALAR) REARED IN SEA CAGES

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Abstract

Two year classes of Atlantic salmon, represented by a line selected for growth performance and a control line in one year-class and an unselected control line from a similar gene pool in a second year class, were reared in sea cages. These fish were used to evaluate the effects of extended day length, using artificial light from fluorescent tubes, on growth and sexual maturation as grilse (maturation after one sea-year). The incidence of grilse was increased significantly in both year-classes in the select and control groups, following exposure to an extended day length of 18 hours during the fall and early winter. The fish exposed to extended day length were significantly larger than the untreated fish following treatment. A reduced incidence of grilse in a select line, compared with unselected controls, suggests that the correlated response in maturation as grilse was negative when selection was applied to fork length of grilse. Conversely, extended photoperiod increased both size and incidence of grilse.

Introduction

Sexual maturation affects growth of fishes and in the case of farmed salmonids, may partly dictate the size at which they must be slaughtered. When salmonids become sexually mature, their growth rate decreases and flesh quality deteriorates (Aksnes, 1986). Fish need to be marketed before external, secondary sex characters have developed. Consequently, when producing large fish, age at maturation becomes an important economic trait (Gjerde, 1986).

There is evidence of a negative correlation between growth rate and age at sexual maturation (Gjerde and Gjedrem, 1984). The decrease in growth is associated with the onset of maturation (Naevdal et al, 1978), as food energy resources are diverted towards gonadal development rather than somatic tissue growth. Growth before the onset of maturation may be unrelated to age at maturity (Naevdal et al, 1978 and O'Flynn, 1990). Other studies have indicated that faster growing salmon mature earlier (Ritter, 1975; Ritter et al, 1986; Anonymous, Annual Report of Salmon Genetics Research Program, 1986/87; Thorpe et al, 1983). Thus,

selection for rapid growth and late maturation of Atlantic salmon may require special selection and management procedures, since early maturation may be coupled with faster early growth.

It may be possible to select for faster growth in grilse strains and suppress early maturation through environmental manipulation. Gjerde (1986) found extensive variation in the percentage of immature Atlantic salmon and rainbow trout within the same year class, but reared in different cages on the same farm. Saunders et al (1983) reported a higher grilse percentage in certain stocks of Atlantic salmon following sea ranching in contrast with cage rearing. These results suggest that the environment has a strong influence and can greatly affect age at sexual maturation. The objective of this study was to investigate the effect of photoperiod on sexual maturity and growth.

Materials and Methods

The role of genetic and environmental effects on the incidence of grilse was investigated in two strains of cultured Atlantic salmon, designated 85XC and 86XC. The base population of Strain 85XC was

synthesized from crosses among sea-ranched returns which originated from seven different rivers in New Brunswick, Canada. Strain 85XC consisted of a control line of 39 full-sib families and a select line of 42 full-sib families. The select line was established by truncation-mass selection for length at grilse age. Strain 86XC was formed from a similar gene pool as Strain 85XC. No selection was carried out on Strain 86XC. There was only one line of 37 full-sib families . These strains are more fully described elsewhere (Anonymous, 1986).

Fish were examined for maturity in late summer after 70 weeks in sea water and were classified as maturing grilse if secondary sex characteristics were developing. Subsequent dissections at slaughter revealed that three percent of sexually immature fish were misclassified in the earlier inspection. This level of error was assumed to be uniform in all groups.

Photoperiod Effect

Sixty smolts from each family were marked with clips and brands, for identification purposes, and reared in two sea cages. Thirty smolts from each

family were assigned to each cage at random, in each strain. The number of smolts placed in each sea cage was approximately 2600. Some identified smolts, not representative of the strains described, were included to balance numbers per cage.

In each year, one cage (820 m^3) was treated with an extended photoperiod of 18 hours per day (0400 -2200 hr, light 18 hr:dark 6 hr, LD 18:6) during the autumn (August 31-November 23, 1987 and September 7, 1988 - January 27, 1989). The natural photoperiod (LDN) decreased from 13 hr 9 min to 10 hr 14 min for Strain 85XC and decreased from 12 hr 58 min to 8 hr 44 min and increased to 9 hr 33 min for Strain 86XC. Lighting for the extended photoperiod was provided by four pairs of 40W fluorescent daylight tubes (320W total) in four waterproof acrylic tubes suspended 1m above the water surface. Photoperiod was controlled by automatic timers, which switched lights on and off without simulated dawn or dusk. No cage covers were used for either treatment.

Fish from Strain 85XC, both natural and extended photoperiod treatments, received a moist feed (Connors) three times a day at 8.00 a.m., 1.00

p.m., and 4.00 p.m.. The temperature ranged from 11.2 °C in September 1987 to 6.9 °C in November 1987 throughout the experiment for Strain 85XC. Fish from the natural photoperiod group of Strain 86XC were also fed moist feed (Connors) three times daily, at 8.00 a.m., 1.00 p.m. and 4.00 p.m. throughtout the experiment. The extended photoperiod group were fed five times daily, at 5.00 a.m., 8.00 a.m., 1 p.m., 4.00 p.m. and 9.00 p.m.. For the month of January 1989 the fish from both treatments of Strain 86XC did not receive the 1.00 p.m. feeding. The temperature ranged from 11.0 °C in September 1988 to 1.8 °C in January 1989.

Statistical Analysis

A general linear model analysis was used to investigate the effect of photoperiod on maturity in the control and select lines of Strains 85XC and 86XC. An analysis of variance was performed on the data, using angular transformed values of the proportion of fish mature ($\sin^{-1}$/proportion of grilse) per family in each cage to investigate the effect of photoperiod on early maturation, with the model:

$$Y_{ij} = \mu + F_i + C_j + e_{ij}$$

where

Y_{ij} was arcsine of the square root of the proportion mature or deformed,

μ was the overall mean,

F_i was the random effect of the i^{th} family (i = 1 to 37 for Strain 86XC, 1 to 42 for the select line and 1 to 39 for the control line of Strain 85XC),

C_j was the fixed effect of the j^{th} cage (j = 1 to 2) and

e_{ij} was the residual associated with the ij^{th} record.

. Results and Discussion

The incidence of grilse was consistently increased with the extended photoperiod treatment (Table 1). The increase from 48.0 to 60.2 percent in the case of Strain 86XC was higher than that in Strain 85XC, where 86XC had a generally lower incidence of grilse. Selection in Strain 85XC was based on grilse fork length. A slightly lower percentage of grilse [61.8 (natural photoperiod) and 69.9 (extended photoperiod)] was found in the 85XC select line, compared to the control line [67.5 (natural photoperiod) and 73.6 (extended photoperiod)]. These results suggest that selection

for grilse length decreased the incidence of grilse, although the selection experiment was not replicated across gene pools.

The evidence of increased growth associated with the extended photoperiod is most noticeable in Strain 85XC, where the LD 18:6 fish were significantly ($P<.01$) shorter than the LDN fish at the start of the photoperiod treatment, on August 31st after 15 weeks in sea water, but were significantly longer at the end of treatment. These results agree with those observed by Hansen at the Institute of Marine Research in Norway (pers. comm.). Similarly, in the case of Strain 86XC, where the initial measurements were recorded five weeks after the commencement of the treatment, the fish in the treated group were significantly ($P<.01$) longer than the fish in the untreated group. These treatment effects on length persisted after the completion of the treatments at 70 and 57 weeks in sea water for Strains 85XC and 86XC respectively, even though much of the food intake would have been expected to be directed toward gonadal growth in grilse by 70 weeks in sea water.

In general, the extended day length was associated with increased size, either with or without additional feeding. However, increased incidence of grilse decreases the usefulness of the treatments, applied in this experiment, where the sea-cage industry encounters marketing problems with the secondary sex characteristics and lowered flesh quality associated with grilse. In contrast to the increased percent grilse associated with increased growth due to the extended photoperiod, a decrease in percent grilse was associated with the positive genetic gain realized in the selection for increased fork length at grilse age (Friars et al, 1990), as depicted in the data in Table 1. Hence, these results suggest a positive environmental but a negative genetic association between growth and grilsification. Thus, the use of extended photoperiod to increase growth rate in multi-sea-winter stock may be more applicable than in one-sea winter (grilse) stock. Other techniques, such as selection for increased growth rate before grilsification, induction of triploidy, production of all-female progeny, or other modifications of the lighting system, may make such management practices practical.

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Table 1. Length and percent grilse for natural and extended photoperiods.

Trait	Wks in sea water	Strain and Line: 85XC Control Nat	85XC Control Ext (15-27)[1]	85XC Select Nat	85XC Select Ext (15-27)	86XC Nat	86XC Ext (17-37)
Grilse (%)		67.5	73.6*	61.8	69.9**	48.0	60.2**
Length (mm)	13	289	284**	296	291**		
	27	438	446**	449	457**		
	70	660	670**	682	689*		
	22					411	415**
	57					553	555*

[1] Figures in brackets indicate the interval of the photoperiod treatment in terms of the weeks the fish were in sea water.

* Difference significant at $p < .05$.

** Difference significant at $P < .01$.